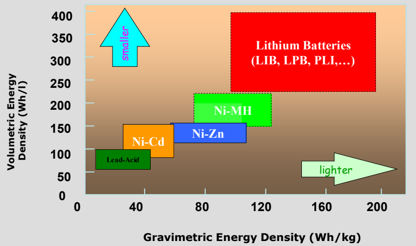
# R&D on Advanced Lithium Batteries

Gary Henriksen, Electrochemical Energy Storage Department, E-mail: henriksen@anl.gov

## Lithium Batteries Offer Best Performance




## Development of Advanced Materials

### Anode Materials

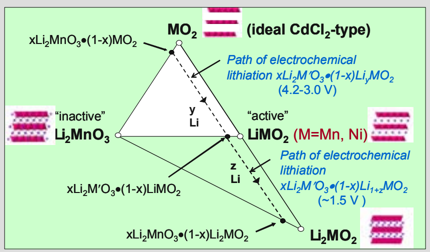
- Lithiated intermetallic anodes
- Carbon-coated nanophase lithium titanate anodes

### Cathode Materials

- Lithium-rich composite cathodes (w/high Mn content)
- Surface-treated lithium metal oxide cathodes
- Surface-coated lithium metal oxide cathodes
- Carbon-coated lithium iron phosphate

### Electrolyte Components & Systems

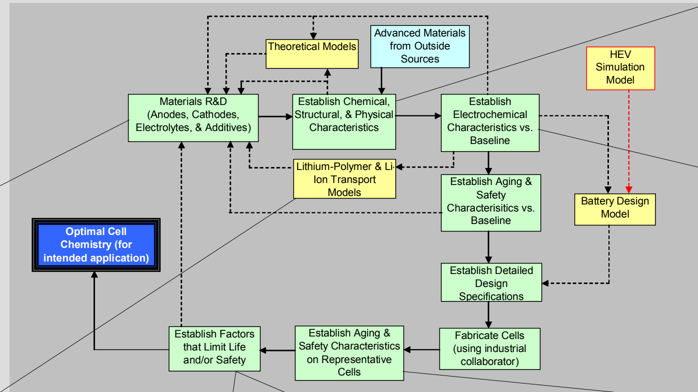
- Additives that form more stable SEI layers
- Additives as flame retardants for organic carbonates
- Additives that establish redox shuttle & prevent cell overcharge
- More stable & non-flammable solvent systems

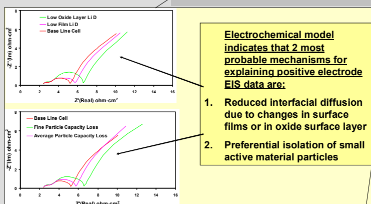



Argonne has a large portfolio of intellectual property covering its advanced materials, including patents on a family of composite cathode materials.

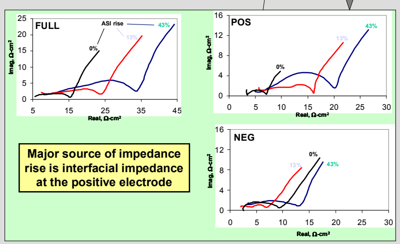
## Argonne's Battery R&D Process

Advanced materials & optimal cell chemistries are developed in the context of understanding the fundamental limitations of existing materials. This flow diagram illustrates the process used to develop more optimal materials and cell chemistries for hybrid electric vehicle batteries.

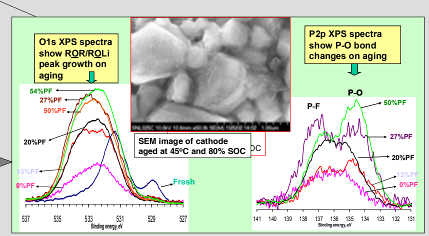


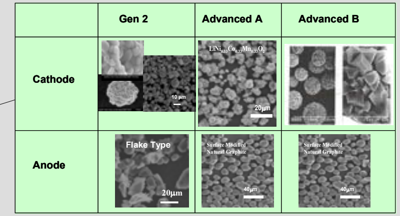

Electrochemical model is used to validate the significance of observed physical & chemical phenomena.



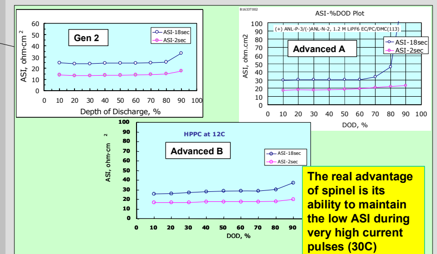

Electrochemical impedance data on electrodes harvested from aged cells show that the main source of impedance rise is interfacial impedance at the cathodes.



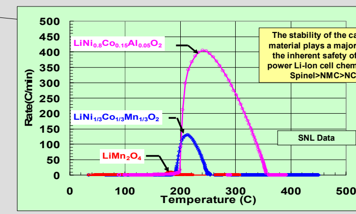

XPS and SEM data on harvested cathodes show a film on the surface of the cathodes & its chemical composition changes as the cells age.



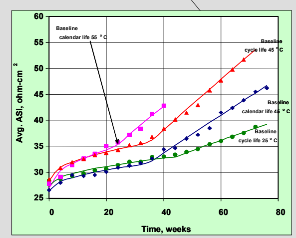

SEM images of alternative anode and cathode materials for use in high-power Li-Ion batteries for hybrid electric vehicle applications. The physical and chemical properties of these materials control their performance in Li-Ion cells. Spherical round edge particles of the proper size are desired for optimal performance, life, and safety.




Area specific impedance values measured, using FreedomCAR test protocols, on cells containing alternative cathode materials show their ability to meet performance requirements.




Comparative accelerated rate calorimetry (ARC) tests show the reduced thermal reactivity of cells that employ alternative cathodes to our Gen 2 cathode material.




Accelerated aging of cells that contain our Gen 2 cell chemistry indicate that this chemistry will not provide the required 15-year calendar life.

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